The *Iowa Stored Energy Plant*

DOE Energy Storage Systems Program

Annual Peer Review

November 10 - 11, 2004 – Washington, D.C.

Bob Haug, Executive Director

Iowa Association of Municipal Utilities

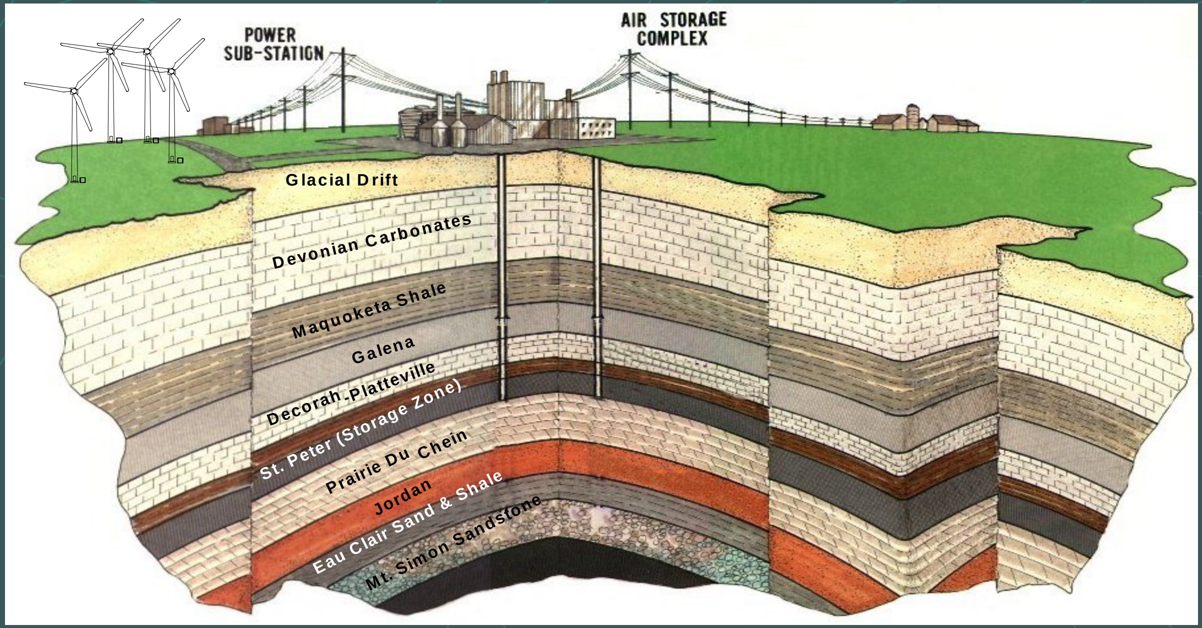
ISEP Project Team

- Project Development Committee: Kent Holst, Chair (Traer): Tom Wind, Consulting Engineer; John Bilsten (Algona); Tom Gaffigan (Harlan); Jerry Haahr (Atlantic); Neil Ruddy (Carlisle); and IAMU support staff
- Funding sources: 74 municipal utilities ($655,000); Iowa Department of Economic Development ($50,000); US Department of Energy ($136,000)
- Project consultants: Burns & McDonnell (preliminary feasibility); Fairchild & Wells (aquifer storage study); Black & Veatch (market analysis, optimal dispatch, proforma investment & cash flow)

Iowa Association of Municipal Utilities (IAMU)

- IAMU members include 550 Iowa cities
  - 550 municipal water utilities
  - 136 municipal electric utilities
  - 50 municipal gas utilities
  - 27 municipal telecommunications utilities
- The Iowa Stored Energy Plant (ISEP) is an IAMU power supply project funded by 109 municipal utilities located in Iowa, Minnesota, and the Dakotas

The Iowa Stored Energy Plant (ISEP)

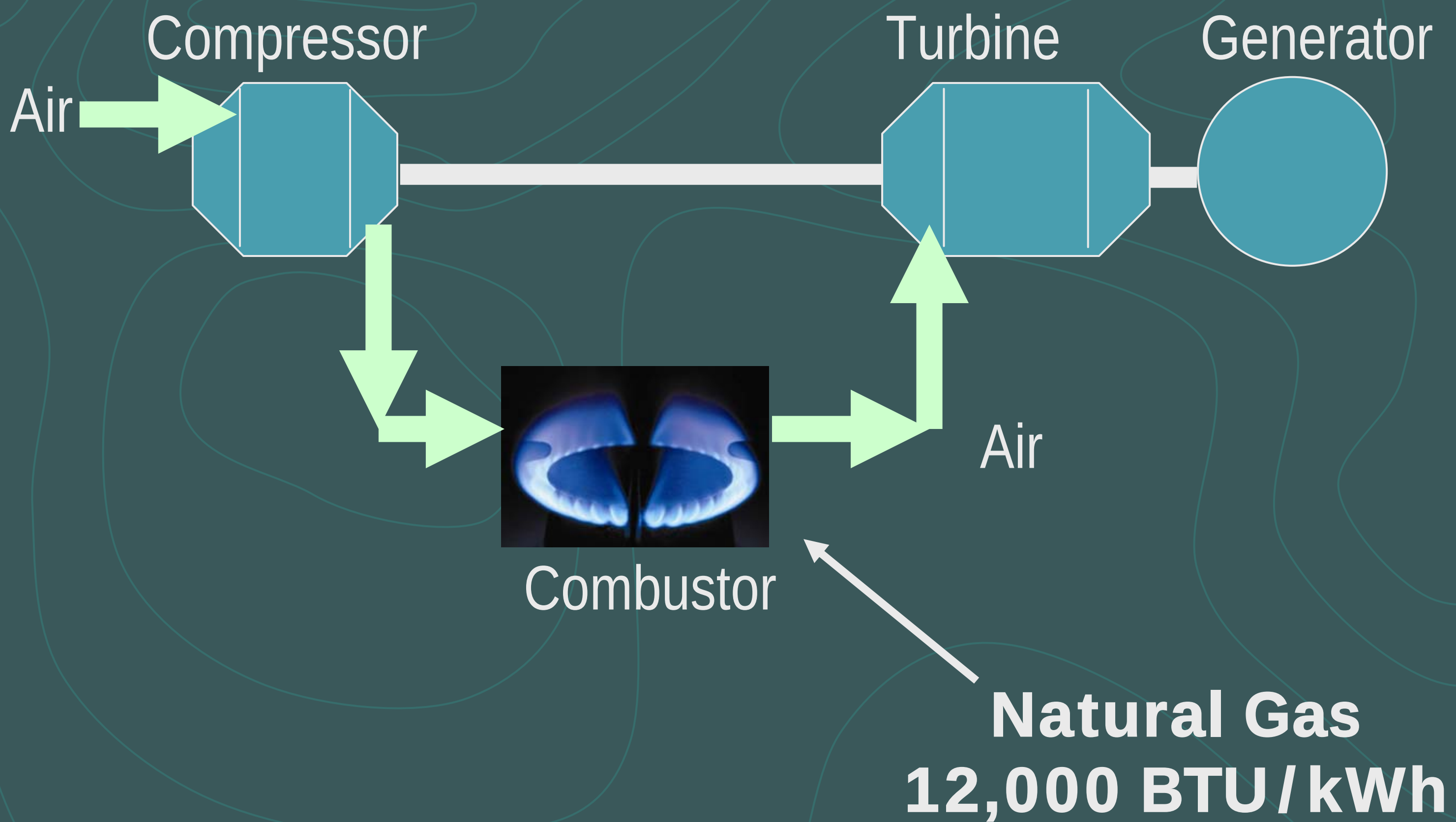


ISEP represents a unique marriage of three known technologies: combustion turbines, aquifer storage of gases, and renewable wind energy

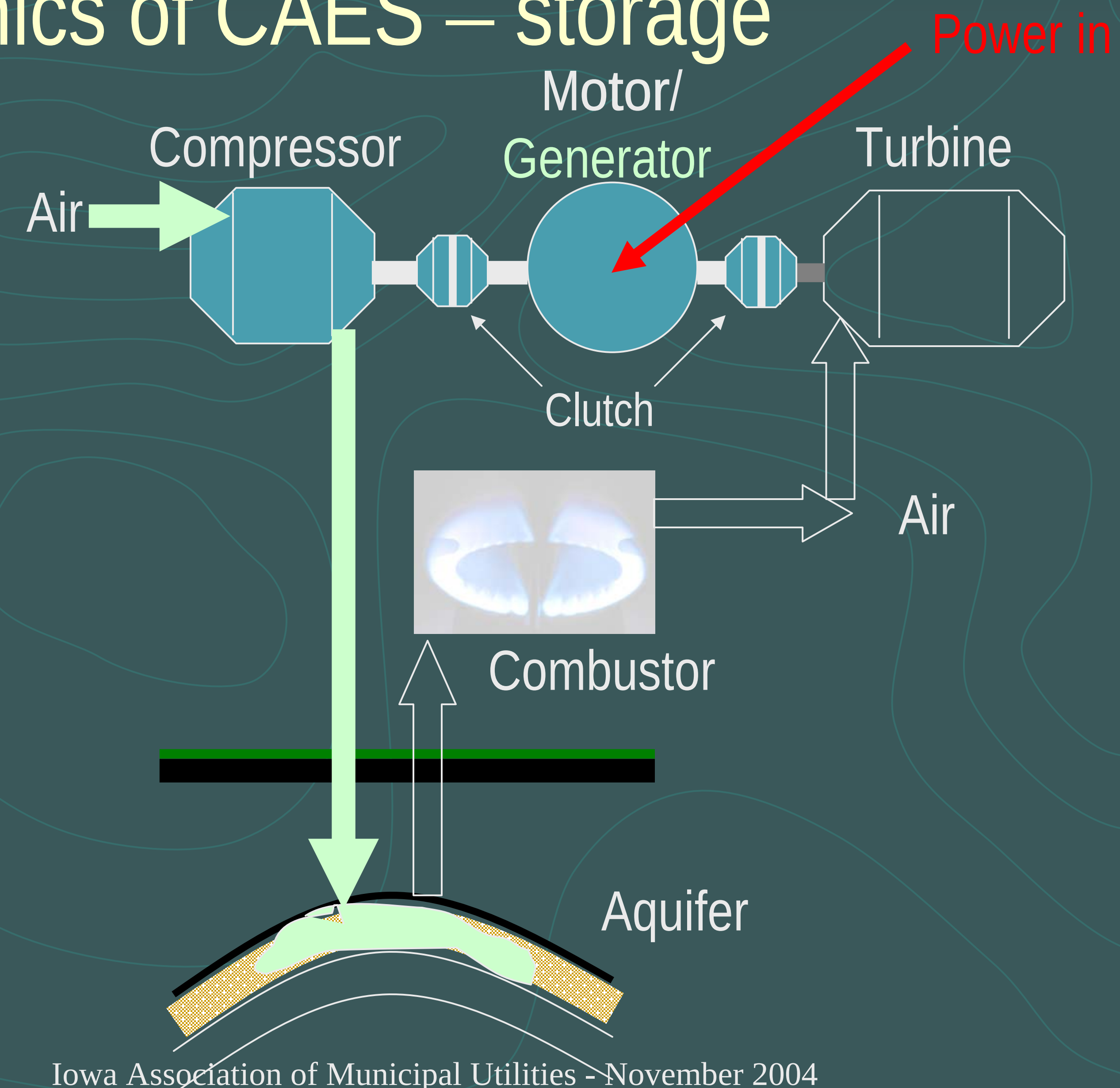
Compressed Air Energy Storage (CAES)

- Fundamentals of CAES:
  - About 2/3 turbine energy used in compression
  - With CAES, air is compressed using low-cost, off-peak energy, including wind energy, and is stored underground
- Two CAES plants are in operation:
  - Germany (290 MW plant operating since 1978)
  - Alabama (110 MW plant operating since 1991)

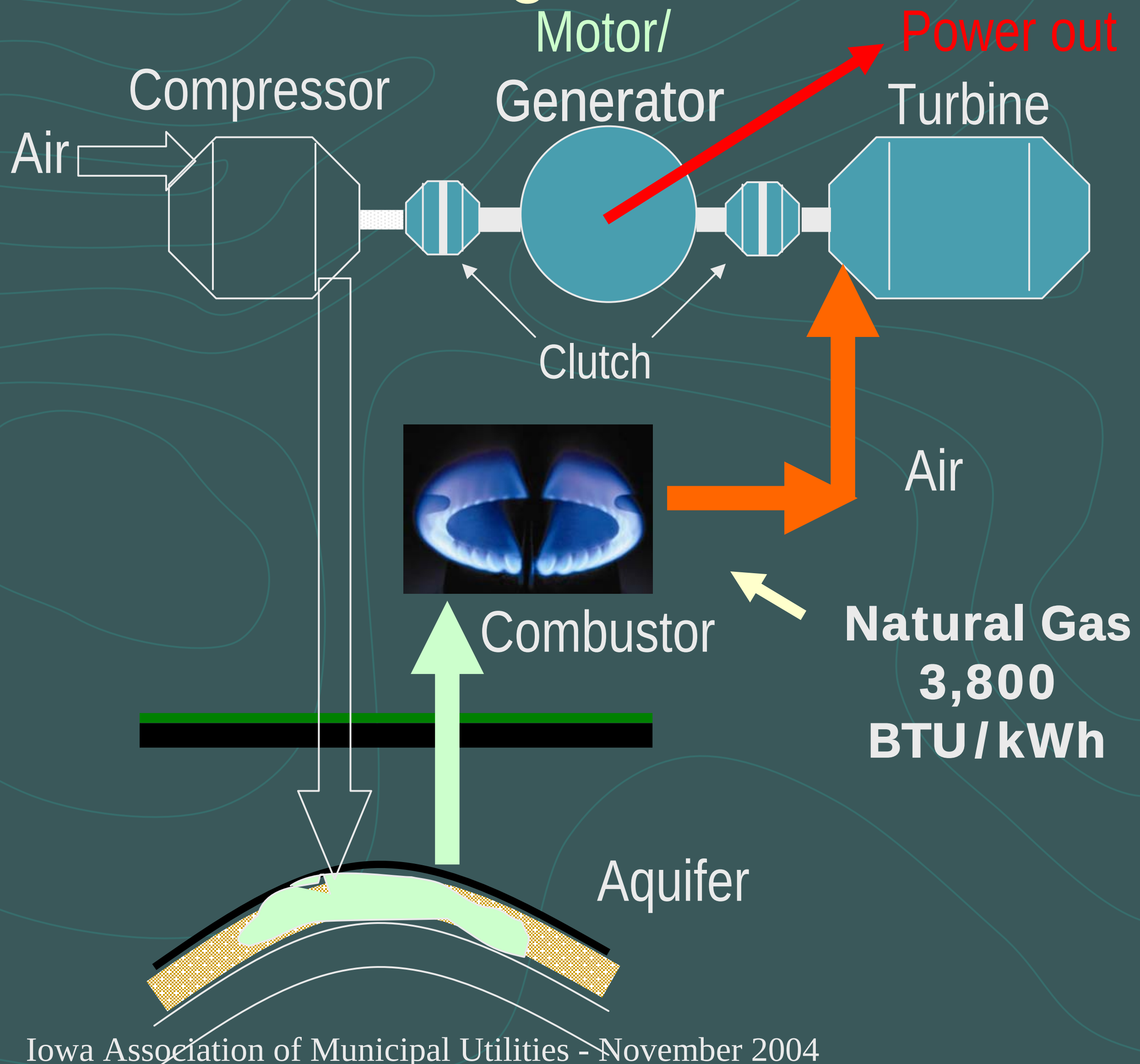
Mechanics of simple cycle turbines



Mechanics of CAES – storage



Mechanics of CAES – generation



Mechanics of CAES – reliability/performance

- CAES uses well-proven and highly reliable equipment (common used in petroleum refining)
- Reliability (from Alabama operation)
  - Average 218 starts per year (1996-2001)
  - 90% starting reliability; >97% running reliability
- Quick start capability (Alabama 110 MW unit)
  - 9 min. to full power or 6 min. emergency startup

Mechanics of CAES - performance

- Efficiency of operation
  - CAES uses 4,300 BTU/kWh vs. 12,000 BTU/kWh for simple cycle turbines and 7,000 BTU/kWh combined cycle units
  - Operates efficiently from 10% to >100 output
  - Economically efficient in 100 MW increments
  - Lower temp. (1,600°F vs. 2,200 °F) = longer service life
  - 60% lower emissions than GT
  - Low hot-weather capacity degradation
- CAES is ideal for delivering ancillary services

Other operating information

- ISEP = two 100 MW turbines out at 161 kV
- Compression = 166 MW at 515 psig
- Heat rate (HHV) 4,286 Btu/kW
- Off peak average ambient temperature 44.5 °F.
- Air temp into storage 110 °F.
- Ramp 50% to 100% in 15 seconds
- Low emissions, even at part load
- Black start capability

The Alabama CAES plant

Alabama Electric Cooperative

McIntosh Power Plant

Aerial View

The Alabama CAES plant

Alabama Electric Cooperative

McIntosh Power Plant

Equipment train and piping

CAES drive train (Dresser Rand)

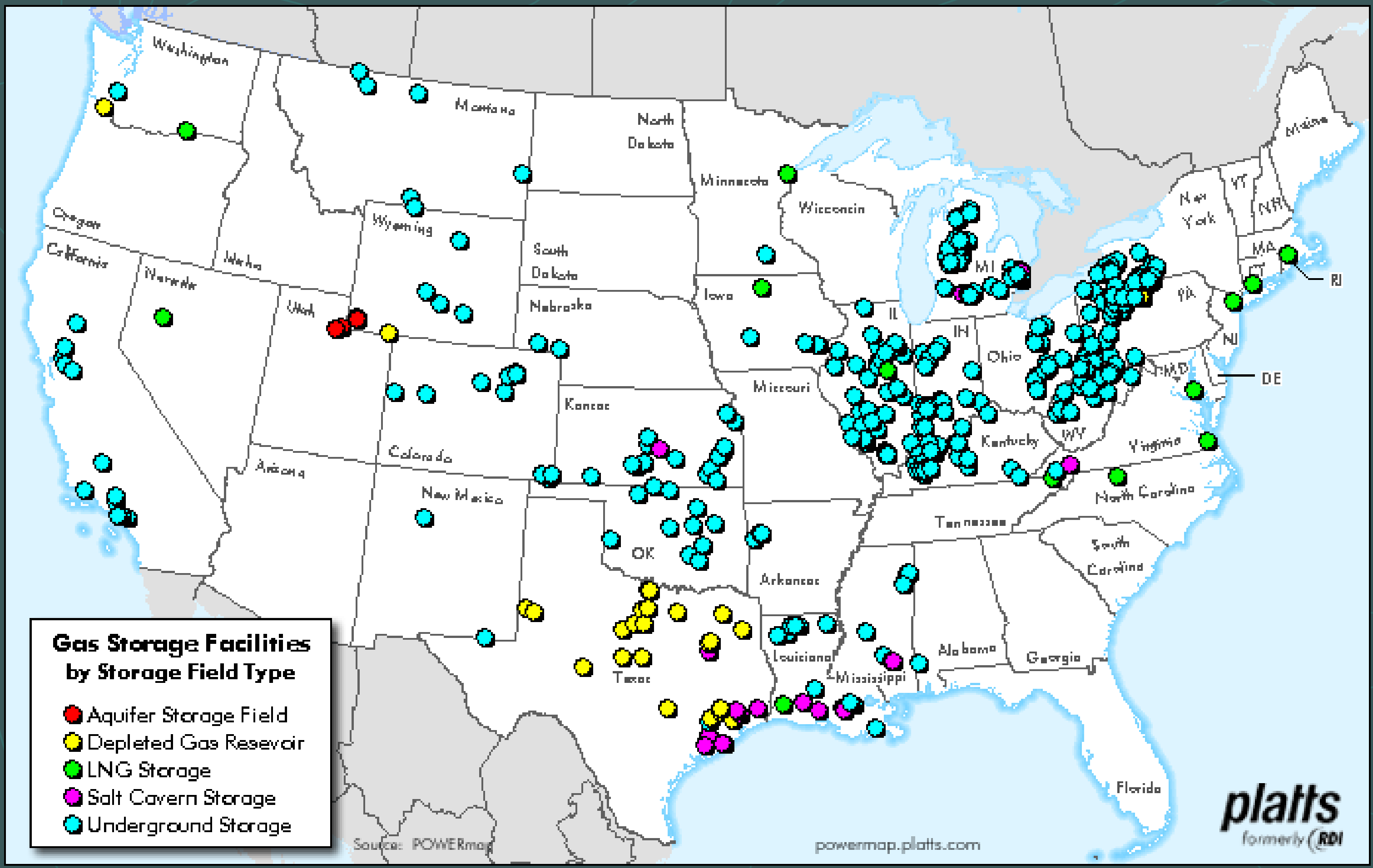
←Motor/
Generator and
Combustion
Turbine

Motor/Generator
and Compressor
Train →

CAES vs. combined cycle gas

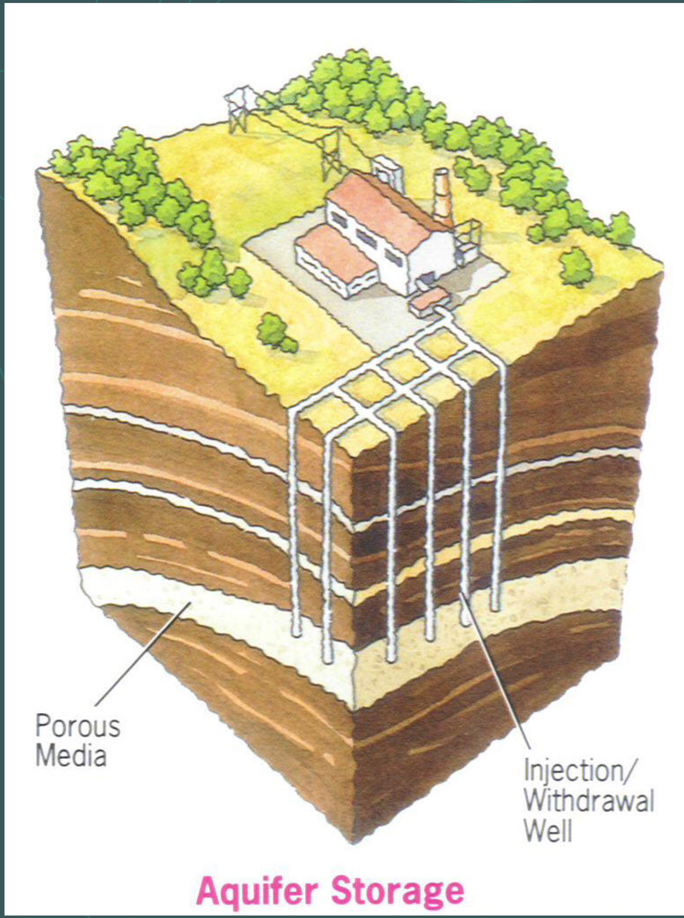
- CAES does <u>not</u> need: Boiler (w/ pipes, steam turbine, & step-up transformer), water treatment, gas & liquid fuel systems, water injection sys., inlet air coolers, cooling tower, waste water sys., firewater sys., DCS control sys., large emergency generator
- CAES needs: Storage aquifer or cavern, air compressor, intercoolers using water from aquifer, two clutches, air recuperater (air to air heat exchanger), air injection/withdrawal wells, compressed air piping
- CAES equipment is simpler w/ lower operating costs

Gas storage



Gas Storage Facilities
by Storage Field Type
Aquifer Storage Field
Depleted Gas Reservoir
LNG Storage
Salt Cavern Storage
Underground Storage
Washington
Oregon
California
Nevada
Idaho
Montana
Wyoming
Utah
Arizona
Colorado
New Mexico
North Dakota
South Dakota
Nebraska
Kansas
OK
Texas
Minnesota
Iowa
Missouri
Arkansas
Louisiana
Wisconsin
MI
IL
IN
Ohio
Kentucky
Tennessee
Mississippi
Alabama
Georgia
Florida
South Carolina
North Carolina
Virginia
WV
MD
DE
NJ
PA
New York
VT
NH
MA
CT
RI
Maine
Source: POWERmap
powermap.platts.com
platts
formerly RDI

Aquifer storage



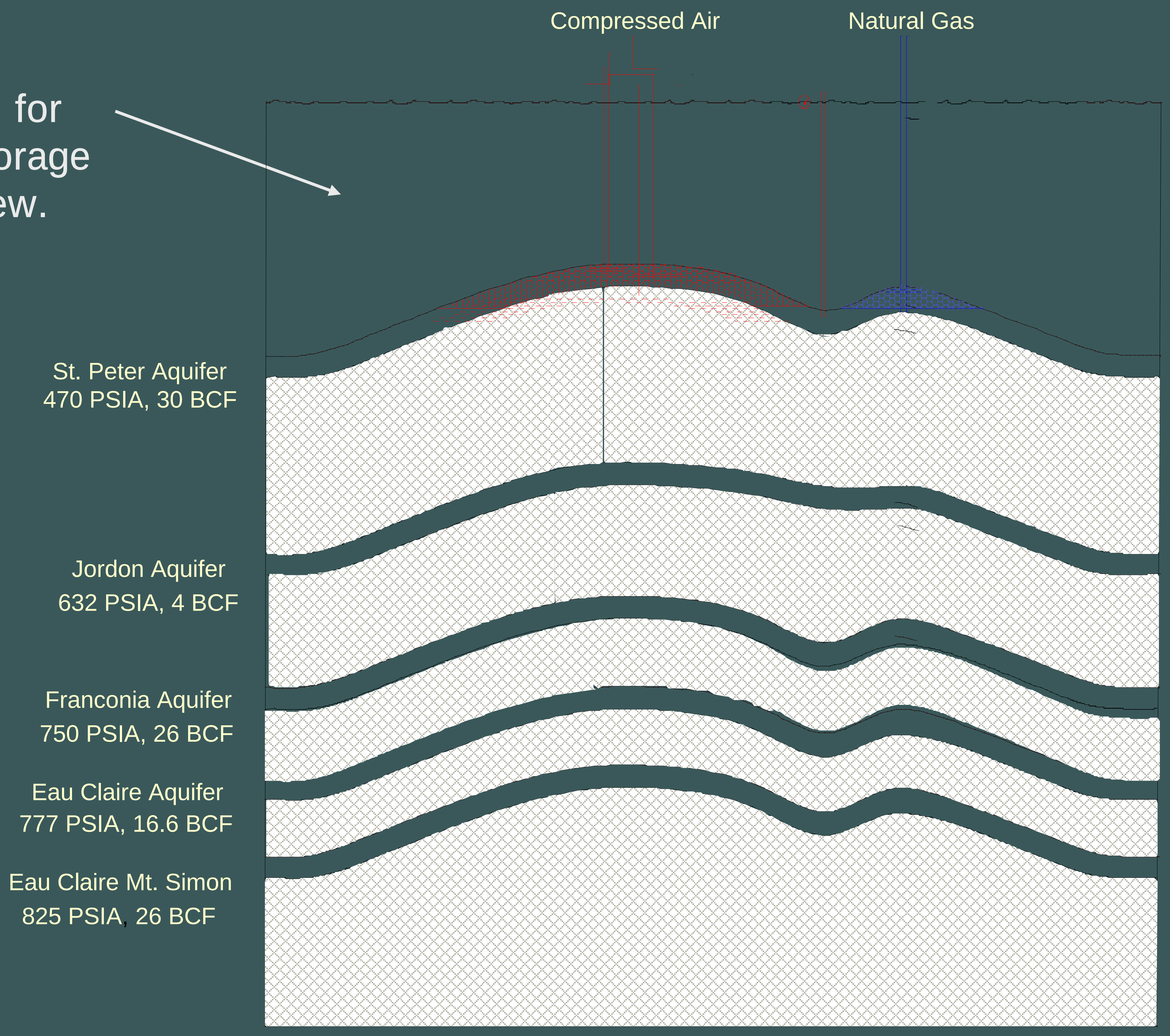
Iowa Stored Energy Plant

Illustration

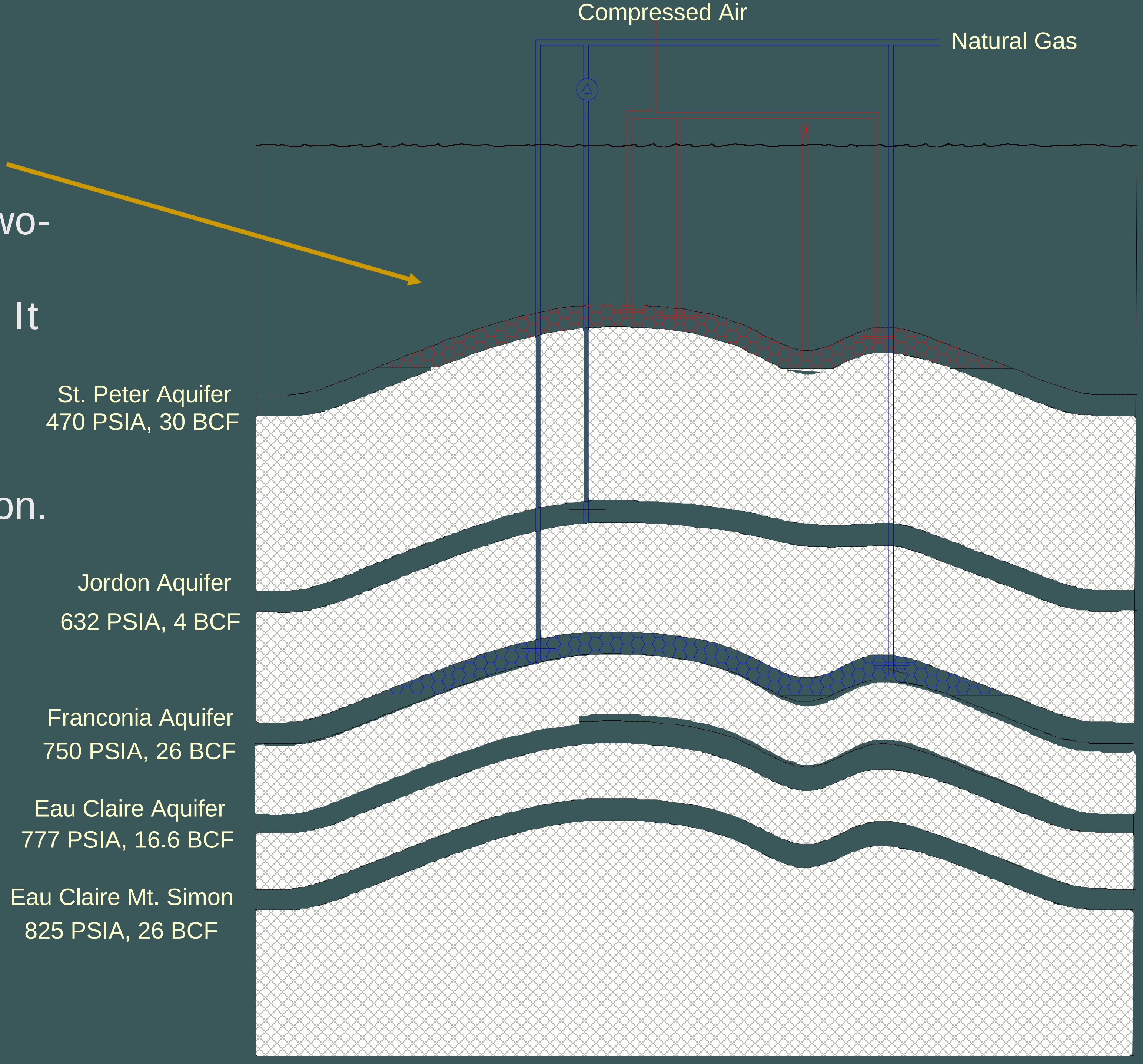
The Iowa CAES site

- Site located in north central Iowa
- Good data on storage capability
- Substantial capacity / good pressure – 1200'/525 p.s.i.
- Very permiable rock with impermeable cap (12,000 milli-darcies vs. ave. in 100s)
- Access to electric transmission
- Gas pipelines at site

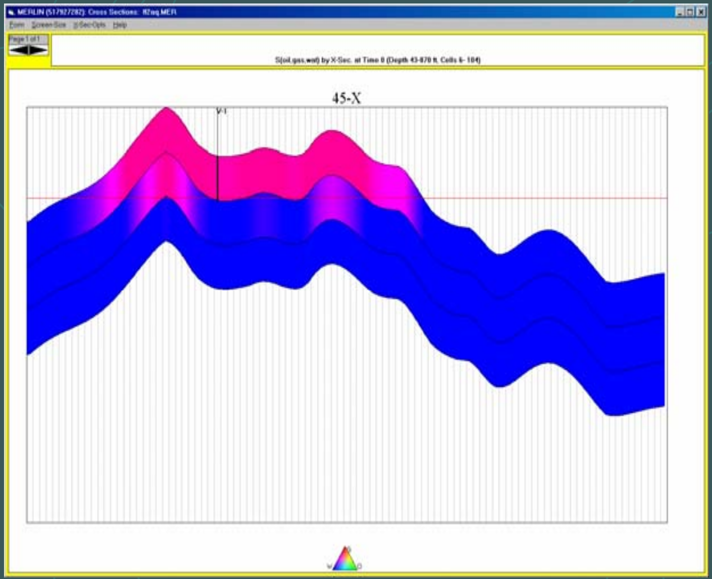
One option for two-gas storage under review.

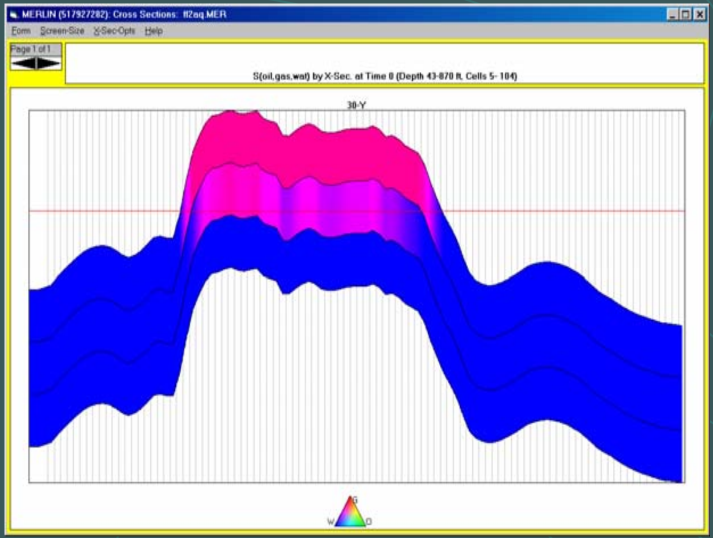


Another conceptual two-gas design is shown here. It depends on extent of vertical communication.



Geophysical data analysis

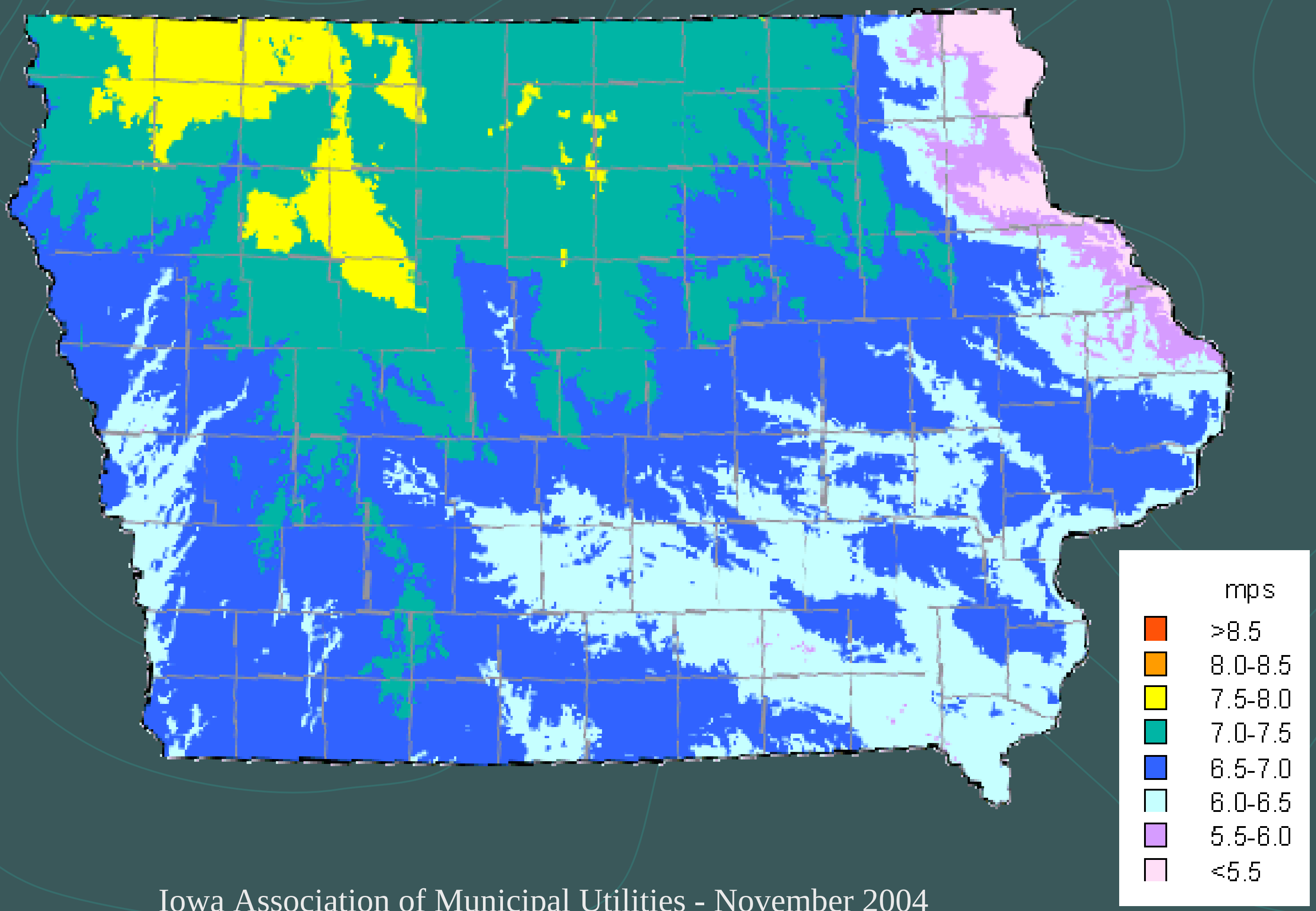




Storage of natural gas

- Key considerations and modifications:
  - Which strata to use (depends on compressor need and storage volume for CAES plant and by utilities/pipeline)
  - Additional wells for injection/withdrawal
  - Use of existing gas from various strata into desired location to be used as cushion gas
  - 1.5 miles of high pressure gas line needed to connect to interstate gas line

Iowa and wind energy

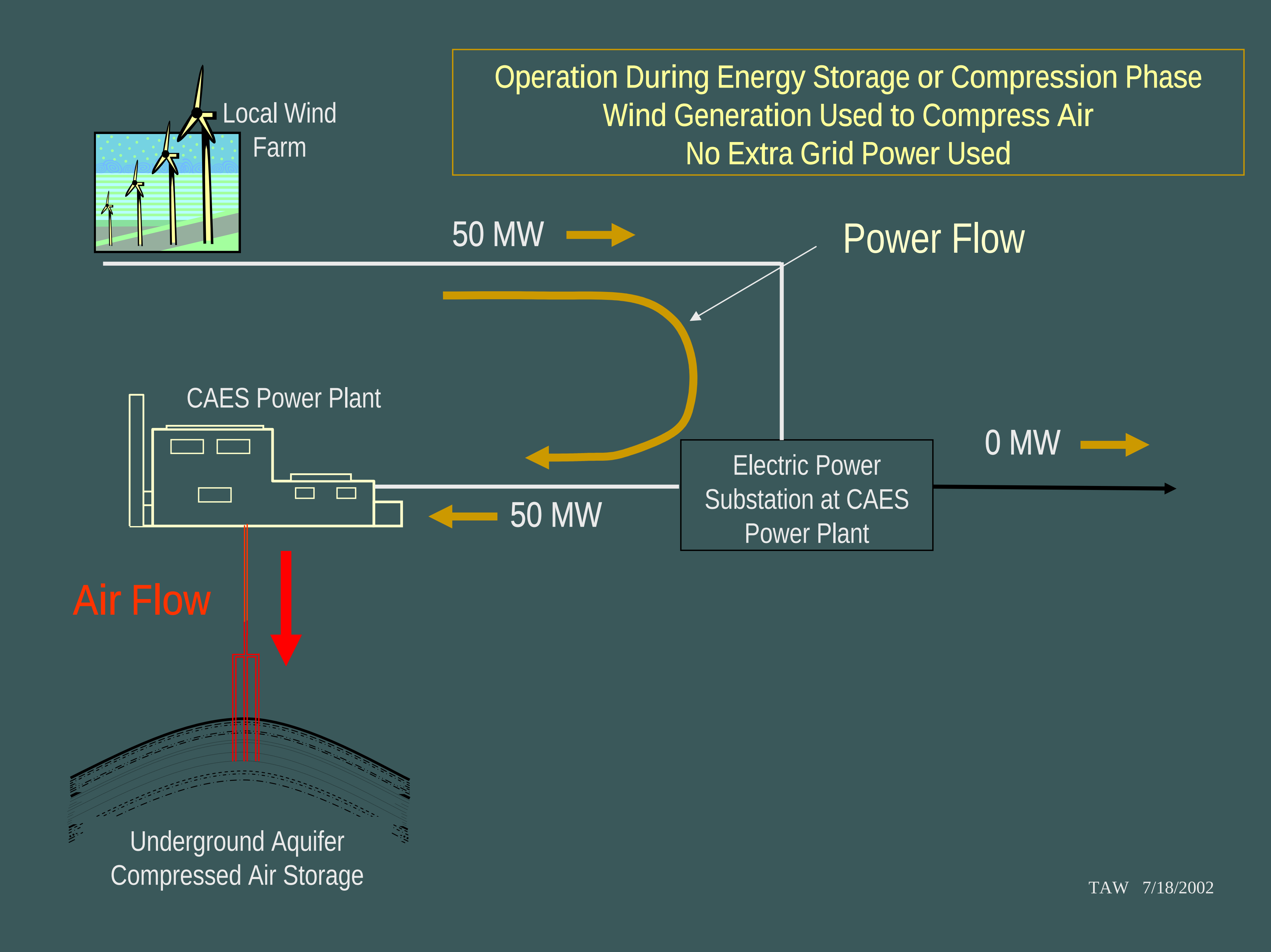


Integrating wind and CAES

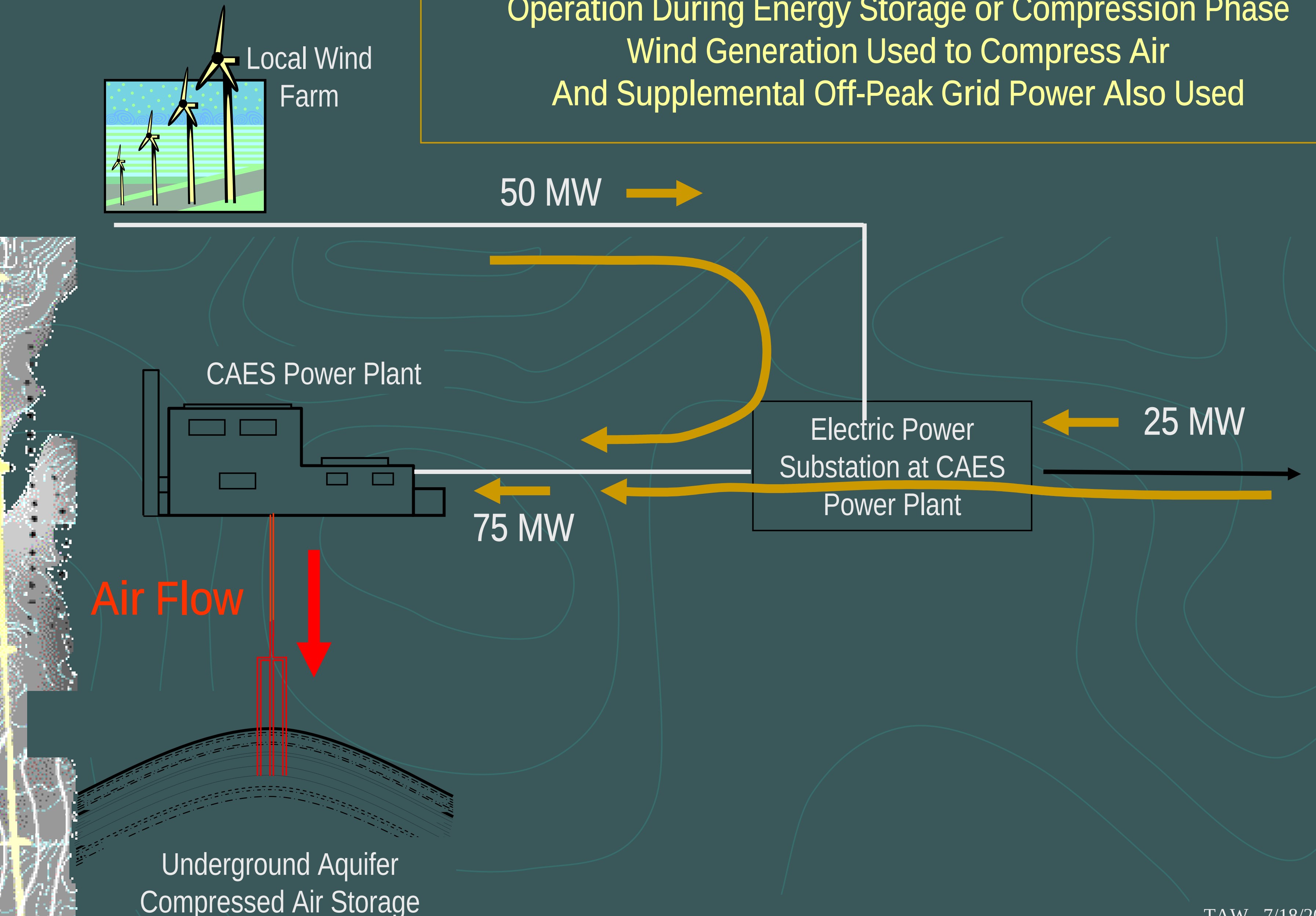
- Wind is low-cost generation source
- Wind is not dispatchable
- CAES provides a battery for wind
- CAES/Wind is dispatchable as an intermediate resource. It has flexibility for operation as a baseload plant.

Integrating wind and CAES

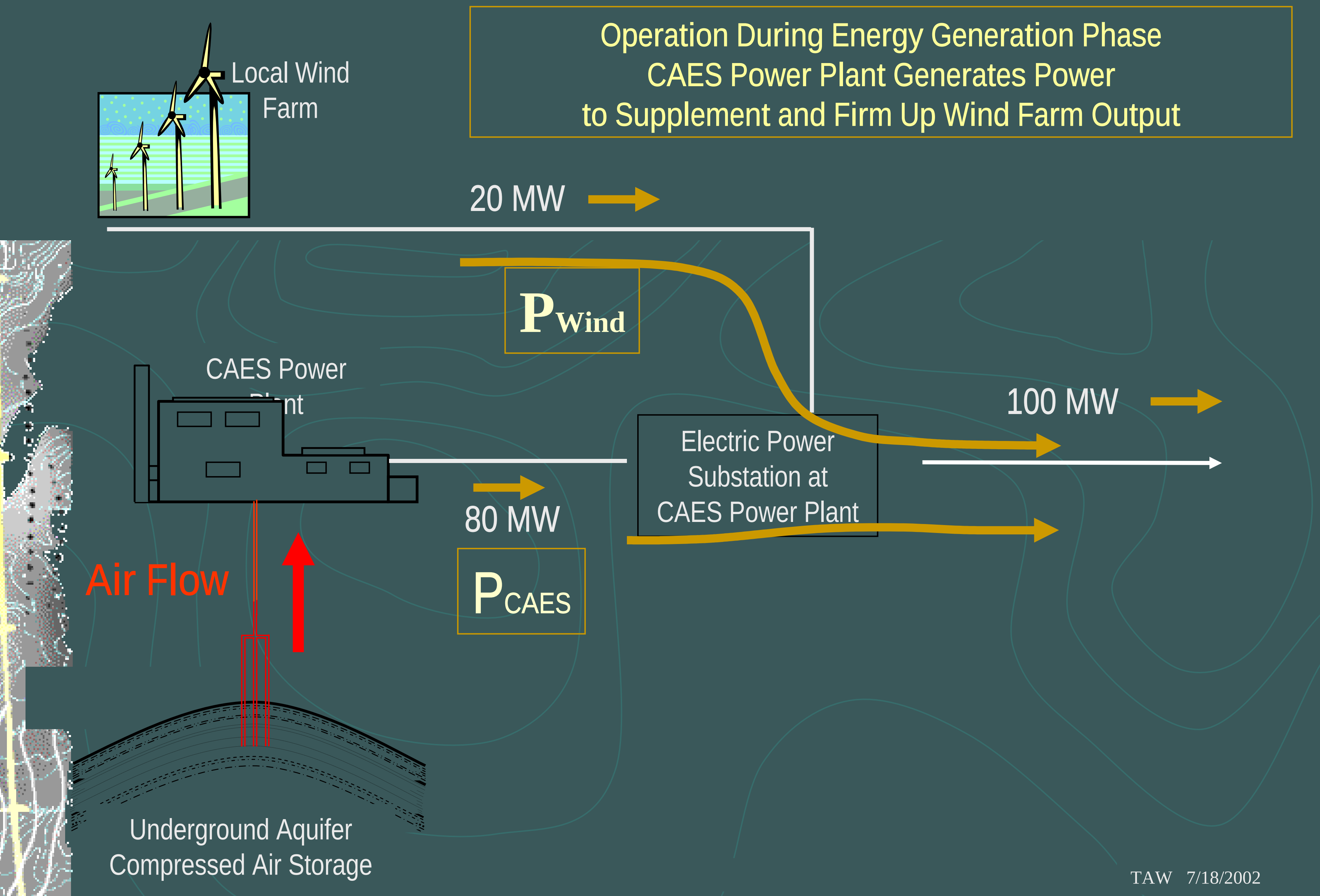
- During the daytime, wind generation would be used to supplement the CAES generator output
  - All wind generation would go directly to grid. CAES generation would make up any difference by following the wind generation pattern to present a firm block of power
  - If wind generation was more than schedule needs, excess could be sent to compressor for storage
- At night, wind generation would be used to replace part of the off-peak energy purchases from the grid
  - If the wind generation was more than the compressors could handle, then the excess would be sent to the grid


Operation During Energy Storage or Compression Phase
Wind Generation Used to Compress Air
No Extra Grid Power Used
Local Wind Farm
50 MW
Power Flow
CAES Power Plant
0 MW
Electric Power Substation at CAES Power Plant
50 MW
Air Flow
Underground Aquifer Compressed Air Storage
TAW 7/18/2002

Operation During Energy Storage or Compression Phase
Wind Generation Used to Compress Air
And Supplemental Off-Peak Grid Power Also Used

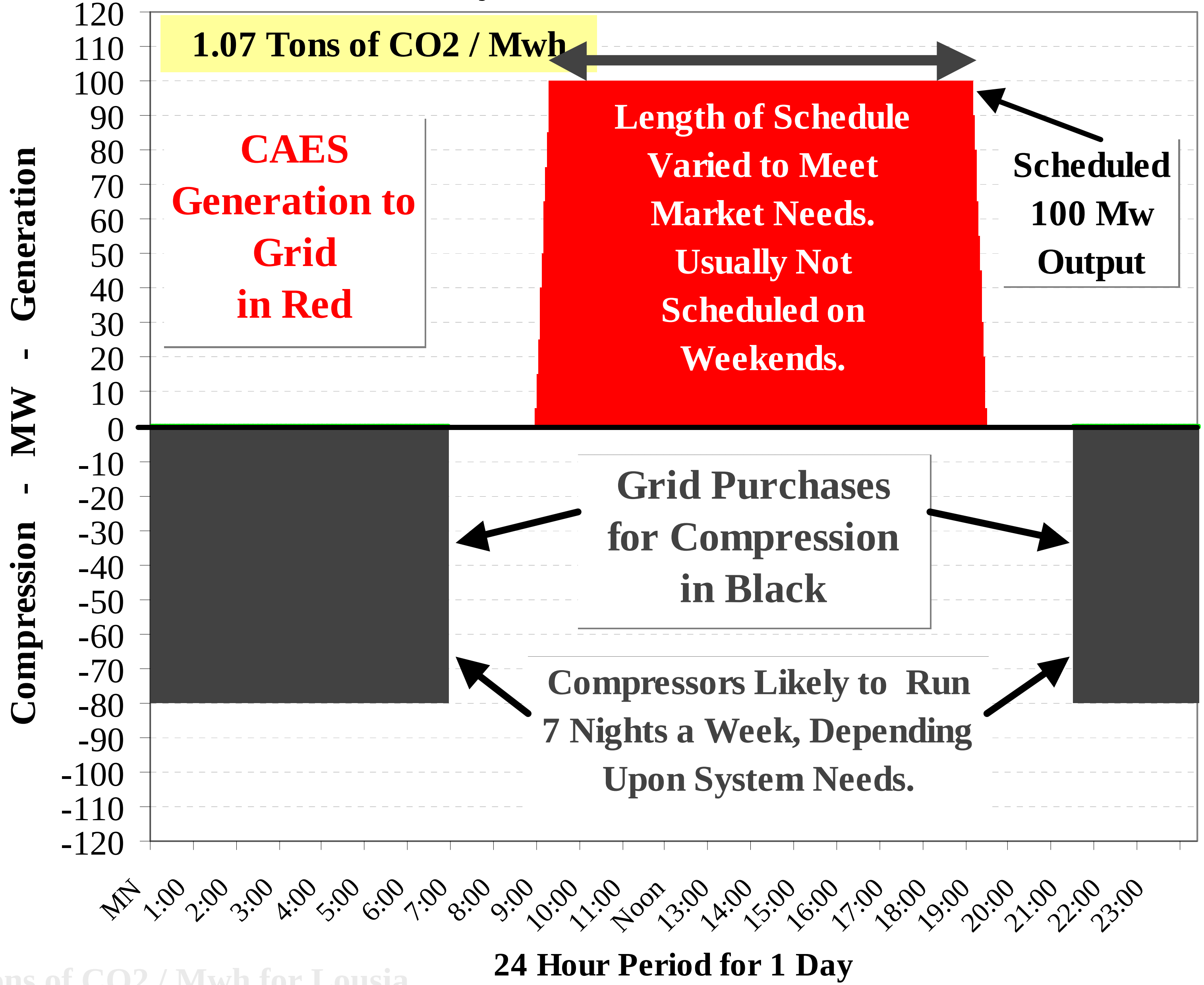


TAW 7/18/2002

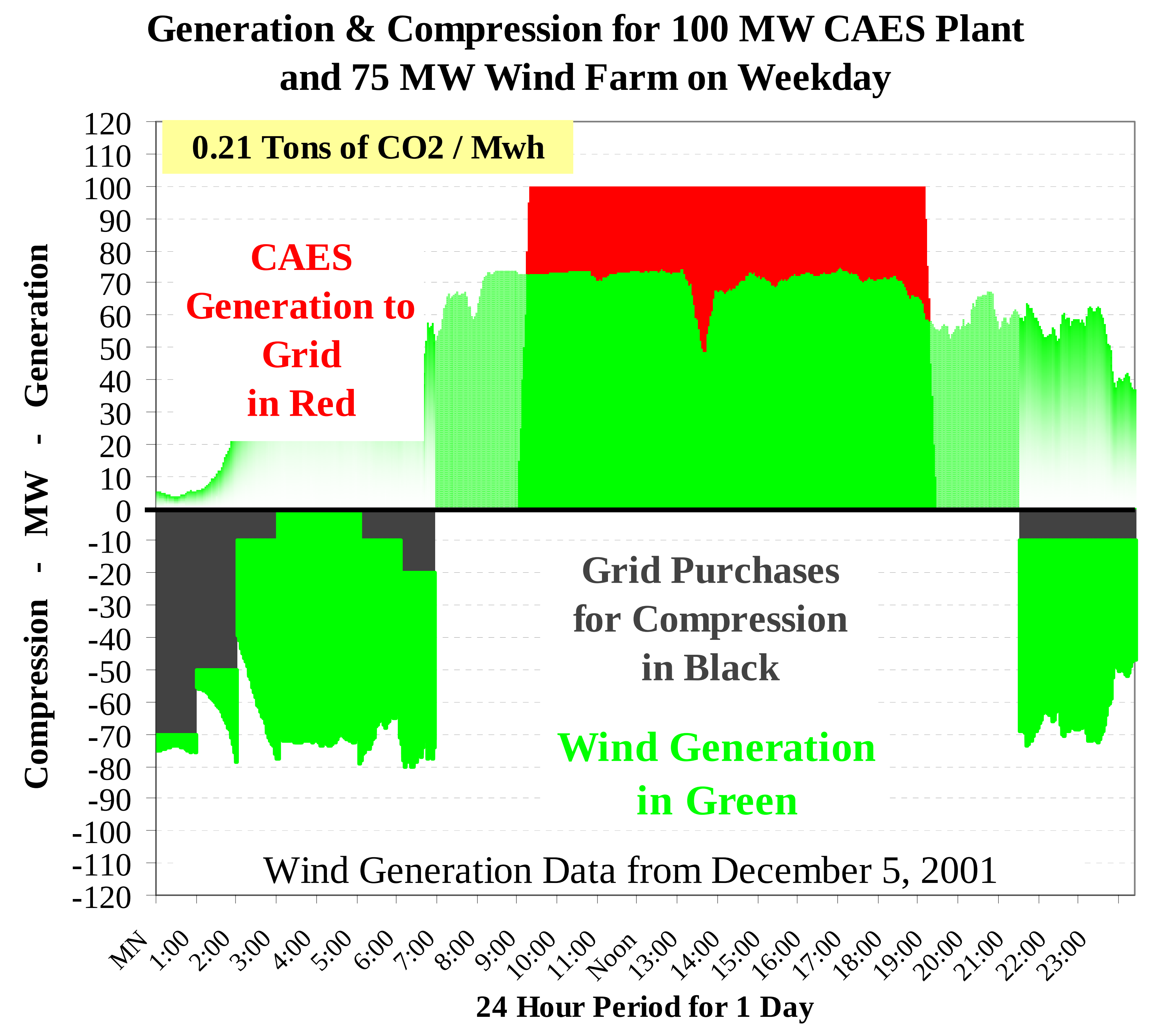


Operation During Energy Generation Phase
CAES Power Plant Generates Power
to Supplement and Firm Up Wind Farm Output
Local Wind Farm
20 MW
P Wind
CAES Power
80 MW
P CAES
Electric Power Substation at CAES Power Plant
100 MW
Air Flow
Underground Aquifer Compressed Air Storage
TAW 7/18/2002

Generation & Compression for 100 MW CAES Plant for One Weekday With No Wind Generation



1.10 Tons of CO2 / Mwh for Lousia



December 5, 2001

Potential revenue offsets

- Ancillary service revenue potential (examples)
  - Load following
  - Var support
  - Spinning reserves
  - Black start capability (may be rewarded after eastern blackout)
  - Green tag value

Why consider carbon costs?

- Because it is the right thing
- Fuel diversification is needed to hedge cost of emissions – Keoto or not – a carbon tax or equivalent offset at $15/ton adds $17/MWH from coal vs. $4/MWH CAES
- Other emission reductions likely, e.g., SO_x particulates, Mercury, others?

400,000 years of $C0_2$ and Temperature Data
Recent Observed and Predicted Change

"Business as Usual"

2100

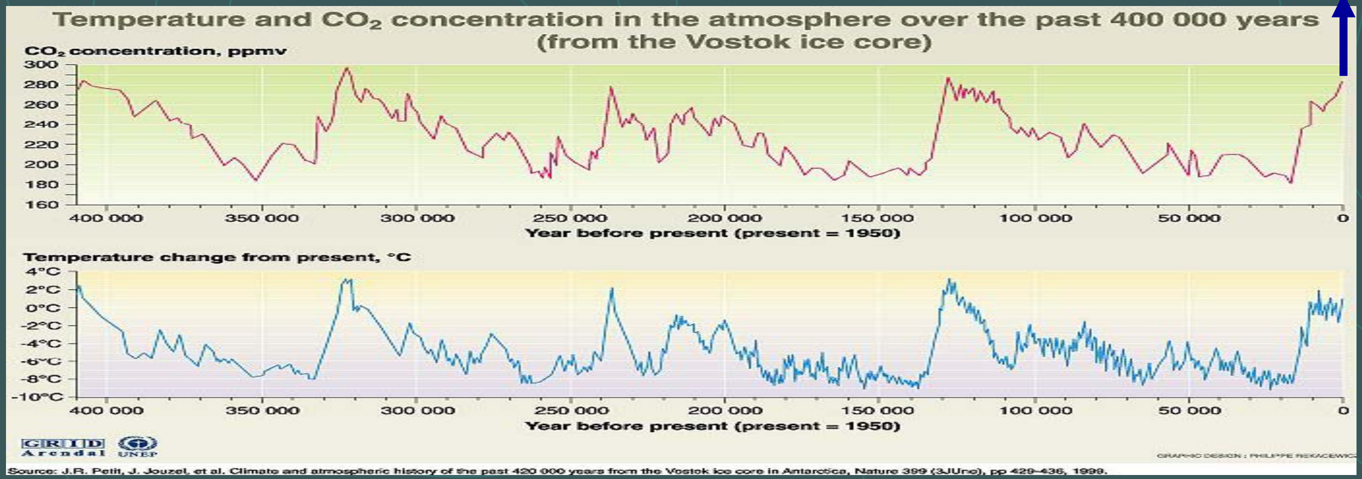
Doubling Scenario
(550 PPM)

2002

1800

CO_2

°C



Summary case for ISEP

- For us, it is a local option for dealing with climate change. It keeps money in the state.
- Supported by customers
  - Very clean plant (local emissions)
  - Uses Iowa's most abundant indigenous energy resource, wind power, to mitigate GHG emissions
- Supported by farmers who receive rents for wind turbines and for gas storage

Summary case for ISEP

- Meets need for intermediate generation with option for base load later
- Good hedge against environmental costs for GHG and other emissions
- Diversifies generation & fuel resources
- Adds renewable resources
- Gas storage under further study

Where things stand

- Municipal utilities have spent about $700,000 to date
- **Plant studies**: Burns & McDonnell preliminary cost study complete, additional DOE-funded Black & Veatch market analysis due November 22
- **Underground Aquifer Storage**: Comprehensive geological analysis and 3-D imaging complete; DOE-funded verification study under way
- **Transmission**: initial studies complete; additional analysis to begin soon

DOE funded studies (tot. $136,000)

- Independent verification of aquifer suitability
  - Subcontractor: Fairchild & Wells, Inc. (Houston)
  - Scope: Review of data from prior investigation of site as gas storage facility, subsequent well logs, ISEP seismic data, and other geological information
  - Finding: Adequate storage for CAES, though some reduction in previously estimated storage capacity
  - Status: Task complete

DOE funded studies (continued)

- Assessment of suitability for two-gas storage
  - Subcontractor: Fairchild & Wells, Inc. (Houston)
  - Scope: Review of data from prior investigation of site as natural gas storage facility, subsequent well logs, AVO seismic data collected by ISEP, and other geological information
  - Initial finding: vertical communication between aquifers appears to limit two-gas option
  - Status: ongoing assessment; report by Dec. '04

DOE funded studies (continued)

- Power market forecast
  - Subcontractor: Black & Veatch
  - Scope: Forecast of 20-year market clearing price for electricity in Iowa
  - Status: Report by November 22, 2004

DOE funded studies (continued)

- Production cost modeling
  - Subcontractor: Black & Veatch
  - Scope: Modeling of CAES plant marginal dispatch costs and operating constraints
  - Status: Report by November 22, 2004

DOE funded studies (continued)

- Financial pro forma analysis
  - Subcontractor: Black & Veatch
  - Scope: Pro forma analysis to determine return on investment, as measured by projected cash flows, net present value, and internal rate of return.
  - Status: Report by November 22, 2004

What’s next?

- Complete studies
- Assess option to replace gas with biomass
- Report to participants
- Solicit capacity commitments
- Find non-muni participants, if needed
- Plant start-up = 3 years from final approval

Discussion

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